Current Practice of Thermoregulation During the Transport of Combat Wounded

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Background: This study evaluated the progress in the treatment and prevention of hypothermia in combat wounded since the October 2, 2006 Joint Theater Trauma System Clinical Practice Guideline (CPG) publication and evaluated the frequency of use and effectiveness of the methods described in the CPG.

Methods: The authors used data obtained from the Joint Trauma Theater Trauma Registry maintained by the US Army Institute of Surgical Research for our analysis.

Results: The issuance of the CPG was associated with a decrease in the incidence of hypothermia (p value = <0.0001). None of the thermoregulatory methods were associated with significantly higher overall temperatures when compared with the others (p value = 0.1062–0.3686) or with hypothermia (p value = 0.1367–0.7992); however, lack of entered prehospital data resulted in a suboptimal number of patients for evaluation in this portion of the study. The wool blanket was the most commonly used thermoregulatory method (prehospital, 72%; interfacility, 49%).

Conclusions: (1) The incidence of hypothermia decreased after the issuance of the JTTS CPG. (2) The standard Army wool blanket is the most commonly used thermoregulatory method during transport in theater. (3) This study did not find a significant difference in the capability of maintaining temperatures between the different thermoregulatory methods used in theater during either prehospital or interfacility transport, or in the incidence of hypothermia between patients presenting from the site of injury or from interfacility transport. (4) Data collected before a Level III facility is not consistently entered into the Joint Theater Trauma Registry.

Key Words: Hypothermia, Combat trauma, Thermoregulation, Thermoregulatory technique, Casualty evacuation.

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Hypothermia has been well documented to be associated with mortality in combat wounded[1–4] and is considered a threat in military operations.[5,6] In October 2006, the Joint Theater Trauma System (JTTS), a military system modeled after the civilian model established by the American College of Surgeons Committee on Trauma, issued a Clinical Practice Guideline (CPG) on hypothermia prevention, monitoring, and management. The purpose of this study was to evaluate the impact of that CPG. To assess the impact, we asked three basic study questions. First, has the CPG had an impact on the incidence of hypothermia in trauma patients in the conflicts in Iraq and Afghanistan? Second, are the CPG guidelines for thermoregulatory methods being followed? Finally, of those thermoregulatory methods used, is there a significant difference in the efficacy of the various devices? Determining how we keep patients warm during transport and evaluating the effectiveness of each of these methods will allow best practices to be disseminated and used throughout the battlefield. The findings from this study can be used to contribute to future improvements in thermoregulation during the transport of combat wounded.

Hypothermia has been traditionally defined as a core temperature <35°C. Because of the unique physiology of trauma patients and the increased incidence of mortality in hypothermic trauma patients,[1–4] a different system of classification was used in this analysis to evaluate the impact in gradations of hypothermia. Hypothermia in trauma patients may be defined as a core temperature <36°C, with further classification described as mild hypothermia (36°F–34°C), moderate hypothermia (34–32°C), and severe hypothermia (<32°C).[2,4,7] In 1995, Gentilello[7] developed this definition on the basis of his earlier work and the differences in clotting times between each level. In examining hypothermia in combat trauma patients, we separately analyzed our data by using both 35°C and 36°C as thresholds for hypothermia to completely evaluate the CPG and the various thermoregulatory methods currently in use on the battlefield.

In the military battlefield trauma setting, hypothermia is a much more complicated threat than hypothermia in the civilian system. Evacuation of a casualty to a medical facility may be delayed for many hours in military settings, increasing the likelihood that hypothermia will complicate trauma management. This problem is exacerbated in helicopter evacuation, where the casualty is exposed to cooler temperatures at altitude and significant wind-chill in an open cabin. Therefore, prevention of heat loss should start as soon after wound-

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ing as the tactical situation permits because the physics of heat transfer make it much easier to prevent hypothermia than to correct it.

Military medicine has placed an emphasis on the prevention and management of hypothermia,[2,3,8–14] resulting in the publication of the JTTS CPG for hypothermia prevention, monitoring, and management.[4] The Committee on Tactical Combat Casualty Care also has published its recommendations for military and other tactical prehospital providers in the Prehospital Trauma Life Support Manual.[15] These recommendations are nearly identical to the CPG recommendations. Both of these organizations' policy statements on hypothermia were in accordance with the publication of the Assistant Secretary of Defense for Health Affairs policy memorandum HA 06-005 from February 16, 2006, which directed all services to maintain patient core temperatures as close to 37°C as possible.[16]

MATERIALS AND METHODS

Materials

Overview of the October 2, 2006 CPG for Hypothermia Prevention, Monitoring, and Management

The Joint Trauma Service recognized the need for improvement and standardization in the prevention, monitoring, and management of hypothermia in theater and issued the CPG on October 2, 2006.[4] It is reviewed and updated yearly. The current update directs that hypothermia prevention be emphasized at all echelons of care and should start as soon after wounding as possible. It also directs frequent temperature monitoring and documentation during transport. The CPG directs mandatory use of the Hypothermia Prevention and Management Kit (HPMK) (described elsewere) for all rotary wing transport of immediate triage category patients and mandatory documentation of temperature upon arrival to and discharge from Level III and Level IIb facilities. After these directives, the CPG offers general recommendations for thermoregulatory method utilization. These recommendations are as follows:

1. Level I (point of injury or battalion aid station): use the HPMK or its separately obtained components.

   Level IIa (area support medical company or brigade support medical company): employ the HPMK or its components, the Thermal Angel fluid warming device, Bair Hugger, and Temp Dots.

   Level IIb (Forward Surgical Team [FST], Field Resuscitative Surgery Suite, or the equivalent) and Level III (Combat Support Hospital [CSH] or the equivalent): maintain a trauma emergency room/operating room temperature of 85°F to 90°F (29.4–32.2°C); use warmed fluids and blankets; use the HPMK or its components, Bair Hugger, Thermal Angel, the Belmont FMS 2000 warmer/rapid infuser, and "temp dots."
2. On any evacuation platform, use the HPMK or its components, or if unavailable, any method possible to reduce heat loss from the airflow through the aircraft or vehicle and the thermal angel fluid warming device.

Description of Thermoregulatory Methods

There are many thermoregulatory methods in use in the current theater of operations. The methods listed below are the items available in the pull-down menu of the Joint Theater Trauma Registry (JTTR) data entry fields. Many of these interventions are also used in combination with one another. The particular methods identified in this study are explained below:

Wool Blanket. This is the ubiquitous green Army wool blanket. It has been issued throughout the spectrum of military healthcare facilities from battalion aid station on the front lines to the CSHs and Air Force theater hospitals (or their equivalent in the combat zone) since the Revolutionary War.

Reflective Blanket. Reflective blanket, also termed space blanket or combat casualty blanket, is another commonly issued piece of equipment available in theater. One side is a metallic reflective coating, with the other olive drab in color. Two versions exist: one thin and very compact and another larger version with plastic thread cross-hatching to increase durability.

Human Remains Pouch. This somewhat morbid item commonly called a "body bag," somewhat morbid item, has been found by service members to be effective in preventing heat loss. The internal leak-proof core acts as an effective vapor barrier and helps to retain heat.

HPMK, (North American Rescue Products). This kit comes in two versions, the initial and current versions. The initial version contained a reflective skull cap, a Blizzard Blanket (essentially a honeycombed space blanket with resealable edges), and a Ready Heat (Techtrade LLC) self-heating shell liner. The self heating shell liner produces heat through an exothermic chemical reaction, and it is placed around the casualty. The Blizzard Blanket is then wrapped around the covered patient, and the reflective skull cap is placed on the patient's head. The current version consists of the Ready Heat liner, and the new Heat Reflective Shell. The Heat Reflective Shell is constructed of a 4-ply composite fabric with a waterproof and windproof reflective layer and integrated hood.

Bair Hugger. The Bair Hugger is a forced-air warming device consisting of a warming unit with a telescoping hose, which attaches to a reinforced paper blanket to capture the heated air forced from the warming unit. It requires electricity.

Methods

We had three basic study questions. First, has the current CPG had an impact on the incidence of hypothermia in trauma patients in the theater of operations? Second, what thermoregulatory methods are being used most often in the current theater of operations? Finally, of those methods used, is there a significant difference in the efficacy of the various devices?

For evaluation of the CPG, we conducted a before-and-after study; to evaluate the prevalence of use of each thermoregulatory method, we used a retrospective cross-sectional design; and to evaluate the efficacy of each thermoregulatory method, we used a retrospective cohort design.

All data presented within this article were obtained under a human use protocol, which received Institutional

Review Board approval from Brooke Army Medical Center in San Antonio, TX. The data were derived from entries in the JTTR, maintained at the United States Army Institute of Surgical Research (USAISR) at Fort Sam Houston, TX. The JTTR was established in 2004 to capture, maintain, and report all battlefield injury demographics, care, and outcomes for both military and civilian casualties who required inpatient care.[8,14,17,18] This information is extracted from patient medical records by USAISR research teams in theater and from medical records once patients have returned to the continental United States.[17,18]

It is common practice in military facilities to measure temperatures of trauma patients rectally; however, as in civilian facilities, one should assume that some of the temperature readings were obtained orally.

Inclusion and Exclusion Criteria

For the evaluation of the CPG, any distinct patient entry in the JTTR with a date of admission to a Level III facility and receiving temperature was included. Patients included in the examination of the various thermoregulatory methods could be US military, US civilian, or foreign nationals with a Glasgow coma scale score of 13 or less who had a thermoregulatory method and a temperature recorded upon admission to a surgical facility. This allowed the largest number of patients with potentially significant injuries to be included. Patients who had received an emergency department thoracotomy were excluded to avoid skewing data with patients for whom thermoregulatory intervention would have little impact on their outcome. Because of ethical concerns, patients designated "special interest" or "detainee" were excluded.

Data Evaluation

To evaluate the impact of the dissemination of the JTTS CPG in October 2006, we queried the JTTR for all patients entered from the inception of the registry in December 2004 through April 2009 (n = 33,931). We included only those patients with a date of admission entered and an initial temperature recorded at a Level III facility (n = 24,981). These records were initially sorted into two groups by month: patient encounters occurring before the CPG being issued (n = 13,134) and patient encounters occurring subsequent to issuing the CPG (n = 11,847). We examined both the percentages presenting hypothermic (defined in this study using both 35°C and 36°C as thresholds) by month and the percentage of the whole who presented before and after the issuance of the guideline, using the χ^2 test to evaluate the effectiveness of the CPG.

To examine the methods of thermoregulation currently used in theater, we performed a retrospective cohort evaluation of those thermoregulatory methods used in theater from October 2007 to September 2008. This was the 1 year immediately preceding the initiation of the study and was thought to include only the most current practices for evaluation. The JTTR was queried for all distinct patient entries during that period (n = 8770), and was sorted further in patients who met the study criteria of Glasgow coma scale score of 13 or less, not a detainee, and those not receiving an emergency department thoracotomy (n = 1,364), who had a temperature recorded upon arrival at a Level III facility and had a thermoregulatory method entered into the database (n = 265). This included both patients presenting directly from the site of injury (n = 202) and those transported from a Level IIb facility to the Level III facility (n = 63). Patients entered into the JTTR were separated into groups corresponding to either prehospital transport (site of injury to a surgical facility [Level IIb or Level III]) or interfacility transport (between surgical facilities [Level IIb to Level III]) and further broken into groups on the basis of thermoregulatory method used.

The χ^2 test or Fisher's exact test was used to compare hypothermia prevalence before and after the issuance of the CPG and to compare the prevalence of hypothermia in patients presenting from point of injury to that of patients presenting from another hospital (interfacility transport). Simple percentages were used to compare the usage of the various thermoregulatory methods during the transportation of injured patients. Data are presented as either percentages or mean ± SD within a table, as appropriate. All statistical analysis was performed using SAS 9.1 (Carey, NC). For analysis, a p value of <0.05 was considered significant.

RESULTS

Effectiveness of the CPG

When using either 35°C or 36°C as the threshold for hypothermia in trauma patients, we were able to show that the CPG was associated with a significant reduction in the number of patients presenting hypothermic (p value <0.0001) (Figs. 1, A and B and 2, A and B).

Frequency of Use and Type of Thermoregulatory Methods Used Regardless of Presenting Temperature, October 2007 to September 2008

Of the 8,770 individual entries into the JTTR during the time period studied, 1,364 met the required criteria, 265 of which had sufficient data entered and available for analysis. The percentages discussed are based on all patients who had sufficient data available for analysis, regardless of their presenting temperature. The methods described are those chosen for "all comers" rather than the hypothermic subset of patients.

This analysis achieved significance. The 265 patients with data available was a sufficient sample size to achieve a power of 0.8 using an alpha of 0.05. The patients who were excluded from our analysis were excluded in a way that did not create bias toward any of the various techniques; they were excluded solely on the basis of data entered (i.e., a thermoregulatory method and a temperature entered in the database) and there were no known confounders that would have caused those data points not to be entered based solely on the device used. Therefore, we think that it is a representative sample that shows that the standard army wool blanket is the most commonly used device.

The method of hypothermia prevention used in patients presenting from the site of injury and patients presenting from a Level IIb facility (Army FST, Navy/Marine Surgical Shock Trauma Platoon or Forward Resuscitative Surgical System,

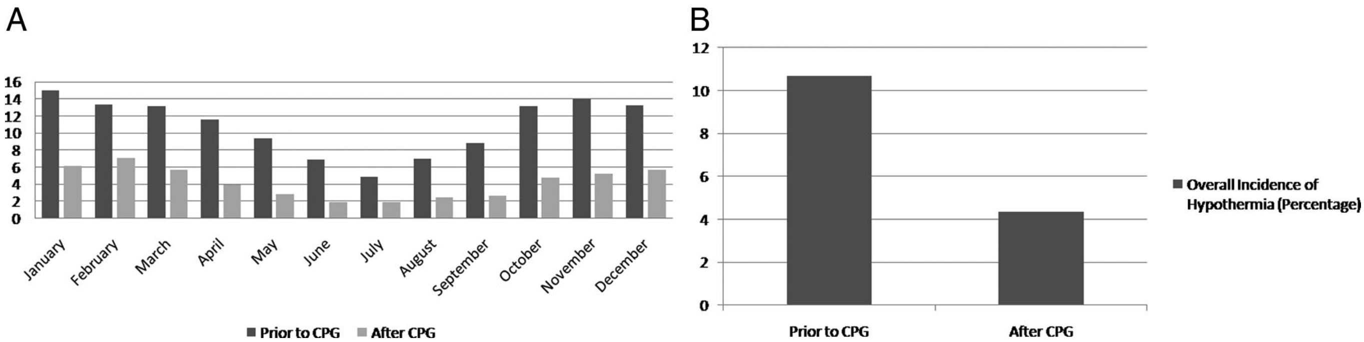


Figure 1. (*A*) Incidence of hypothermia (36°C) by month before and after issuance of the CPG and overall incidence of hypothermia (36°C) (*B*) shown as a percentage of all patients.

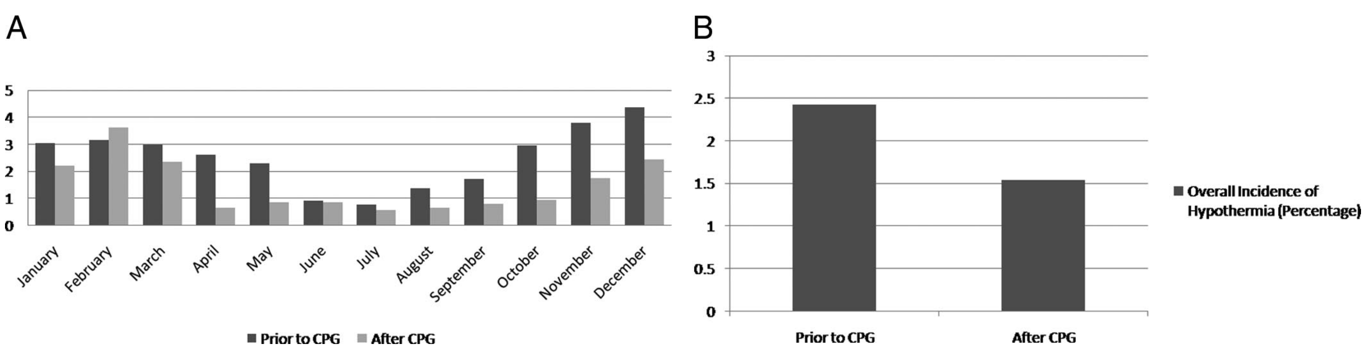
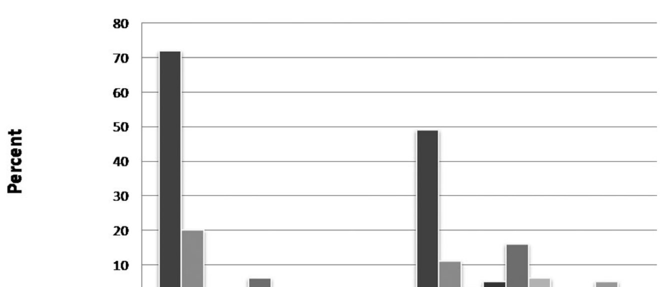


Figure 2. (*A*) Incidence of hypothermia (35°C) by month before and after issuance of the CPG and overall incidence of hypothermia (35°C) (*B*) shown as a percentage of all patients.



	Presenting from Site of Injury (Percentage)	Interfacility Transfer (Percentage)
WB	72	49
SB	20	11
HRP	1	3
HMPK	0.5	5
WB+SB	6	16
WB+SB+HRP	0.5	6
WB+HPMK		2
WB+HRP		2
WB+BH		5
WB+SB+BH		2

Figure 3. Use of thermoregulatory method from site of injury and during interfacility transfer.

Air Force Expeditionary Medical Support, etc.) is shown in Figure 3.

Incidence and Degree of Hypothermia and Initial Presenting Temperatures by Thermoregulatory Method, October 2007 to September 2008

We used various parameters to analyze the efficacy of the various devices. We evaluated presenting temperatures of patients by using the various devices when presenting from both point of injury, and from interfacility transport using both 35°C and 36°C as the threshold for hypothermia. We also examined the mean presenting temperatures of patients using the devices regardless of hypothermia. Because of the low numbers patient entries in each group with the required information entered in the JTTR, we were unable to determine a difference in the efficacy of the various devices (p values = 0.1062–0.7992).

DISCUSSION

The incidence of hypothermia decreased after the JTTS CPG was published. However, it seems that the recommendation for thermoregulatory methods during transport (use of the HPMK or its individual components) has not been followed. The observed reduction in the percentage of patients presenting hypothermic may be primarily because of a cor-

responding increase in attention to the problem of hypothermia rather than because of compliance with the CPG's recommendations on thermoregulatory methods. It is possible that any method with careful attention and monitoring (because of heightened awareness after the issuance of the CPG) may be better than haphazard administration of the best method with little attention paid to the problem of hypothermia. There is at least one other possibility for the reduction of hypothermia independent of a clear benefit of the various thermoregulatory methods. We pose the following question for further study: has raising awareness just given us better data (the denominator suddenly got a lot bigger after the CPG suggested that every patient have a temperature measured on arrival), or has it actually prevented hypothermia? During their evaluation of data for the article, "The impact of hypothermia on trauma care at the 31st CSH" Arthurs et al.[2] found that there were hundreds of patients who did not have an arrival temperature documented. Some of these may have been sick, but presumably, many had very minor injuries and so did not get as much attention—or recording of vital signs. If all these patients had been included in the analysis and assumed to have mostly nonhypothermic temperatures on arrival (that simply were not recorded and so were excluded from analysis), the incidence of hypothermia at the 31st CSH would drop from 18% to 15%. These may be faulty assumptions, but it raises the question whether the difference in the rate of hypothermia during transport pre- and post-CPG, at least in part, is because of data capture.

To answer this question, one needs a documented temperature before transport in addition to the temperature upon arrival at a surgical facility to compare temperature loss during transport with each thermoregulatory method. Unfortunately, patient data collected before Level III facilities is not reliably entered into the JTTR.[2,14] No inconsistencies were found during routine analysis of the data used in this study, but there was a marked lack of data in JTTR patient entries before their arrival at Level III facilities. This is most probably because of the difficulty of the combat environment.

Unfortunately, this study was not able to analyze whether any of the various thermoregulatory methods, specifically the CPG recommended HPMK, were superior in preventing hypothermia. However, recent laboratory testing by Allen et al.[19] at the USAISR has shown that the HPMK was clearly superior to other methods; and further study is ongoing with a porcine model to analyze whether there is similar efficacy in a model with the ability to produce intrinsic warmth.

As shown by the data presented, although multiple technologically advanced thermoregulatory devices are available for use by providers in theater, it is the wool blanket, which has been used since the Revolutionary War, that is still the most commonly used thermoregulatory method during transport in theater.

In search of a cause of this disparity, we considered dissemination of the guidelines, training methods, and availability of the devices in theater. The HPMK is available in the medical system and was recently added to the issued equipment for Army Level I facilities, so availability may not be the issue. Familiarity built during training may play an important role in the choice of thermoregulatory technique for care providers when in combat. Currently, Army medics in advanced individual training use wool blankets or space blankets during their trauma training lanes because of the low cost, durability, and reusability of those products for training high numbers of initial entry trainees. Medics and medical officers conducting predeployment training sponsored by the Army Medical Department Center and School are taught to use the HPMK or its components, but during training, less expensive devices are commonly used. Army FST conduct predeployment training as well; however, it is conducted at a civilian trauma center and focuses on resuscitation and surgical techniques rather than bundling the patient for helicopter transport over the high desert mountains in Afghanistan. Any other training they receive is generally developed by the FST command group and is not standard Army-wide.

On the basis of the laboratory data of Allen et al., wider dissemination and training with the thermoregulatory methods recommended in the CPG may decrease the incidence and degree of hypothermia in combat casualties during transport. Better dissemination of the CPG and the recommendations of the Committee on Tactical Combat Casualty Care to medics and unit providers, and more emphasis on thermoregulation during initial individual and periodic unit training may also improve the usage of these devices.

This study found a significant difference neither in the capability of maintaining temperatures between the different thermoregulatory methods used in theater during either prehospital or interfacility transport nor in the incidence of hypothermia between patients presenting from the site of injury or from interfacility transport. Further prospective study with greater numbers is necessary to confirm the validity of the data presented concerning the effectiveness of the various methods or thermoregulation.

The authors are involved in a 4 year, multicenter study including patients received by the two military Level III centers in Iraq and the US Level III facility at Bagram, Afghanistan. This study will generate a prospective database separate from the JTTR with data collected by onsite research teams funded and manned by the USAISR.

Limitations

Incomplete recording of prehospital and Level IIb data, specifically admission temperature and thermoregulatory method used resulted in relatively fewer patient records, which could be included in this study. This issue has been noted in other research.[2,14]

The wide combination of thermoregulatory methods used resulted in less than optimal numbers of each group for evaluation and decreased our ability to detect a significant difference between groups.

Because of the relatively few numbers of records with documented hypothermia, we did not sort the data for any of the various injury scoring systems or measures of the patient's physiologic status. Likewise, we did not sort on the basis of external factors such as the environmental conditions under which the thermoregulatory methods were used, transport time differences, the use of helicopter or open vehicle

transport, or other factors. Adjusting for these variables with larger numbers might alter the results, and the data presented herein should not be interpreted to mean that all devices or combinations of devices are equal or that they would be equally effective under all conditions.

CONCLUSIONS

The incidence of hypothermia decreased after the development and implementation of the JTTS CPG alluding to the valuable nature of the military trauma system to change clinical practice and effect performance improvement.

The standard Army wool blanket is the most commonly used thermoregulatory method during transport in theater, followed by the space blanket and the combination of the Army wool blanket and the space blanket.

This study did not find a significant difference in the capability of maintaining temperatures between the different thermoregulatory methods used in theater during either prehospital or interfacility transport because of the low numbers with sufficient data entered.

This study did not find a significant difference in the incidence of hypothermia between patients presenting from the site of injury or from interfacility transport, also because of the low numbers with sufficient data entered. Data collected before a Level III facility is not consistently entered into the JTTR.

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